Focused project: High-throughput methods to measure interfacial tension

Combinatorial microfluidic systems will be developed to automatically measure interfacial tension in emulsions. The systems will allow multiple feedstocks to be mixed in a range of compositions.

Today's Outline

- Preview of microfluidic method development in the Processing Characterization group.
  - Major objective: *Analogue of the 4-roll mill*.
    - Versatile test platform, including interfacial tension.
- Trial project and results.
- Specialized device for measuring interfacial tension.

Steve Hudson, Fred Phelan and Joao Cabral

Processing Characterization

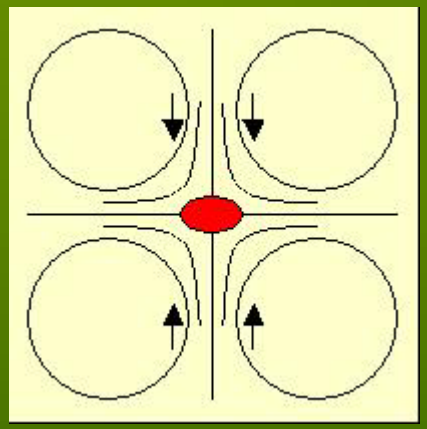
Broad Goal:
Develop microfluidic tools to measure material (and fluid) properties

Example:
Develop a microfluidic analogue for the 4-roll mill.

- Flow modeling
- Device fabrication (as previously discussed)
- Computer control
- A host of applications

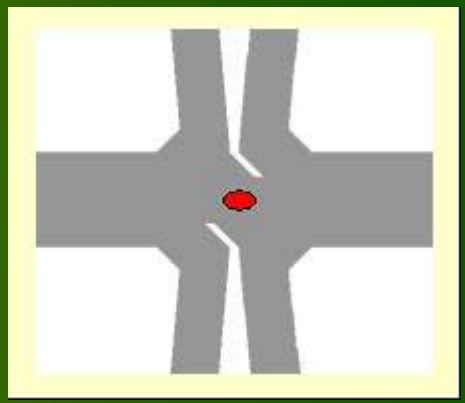
Four-roll mill

4-roll mill



- Adjustable flow type: rotational, mixed and extensional flow. Pure shear is impossible.
- Measure flow-induced properties at long material residence times.
- Applications include flow-induced molecular orientation, particle dispersion, drop deformation and coalescence.

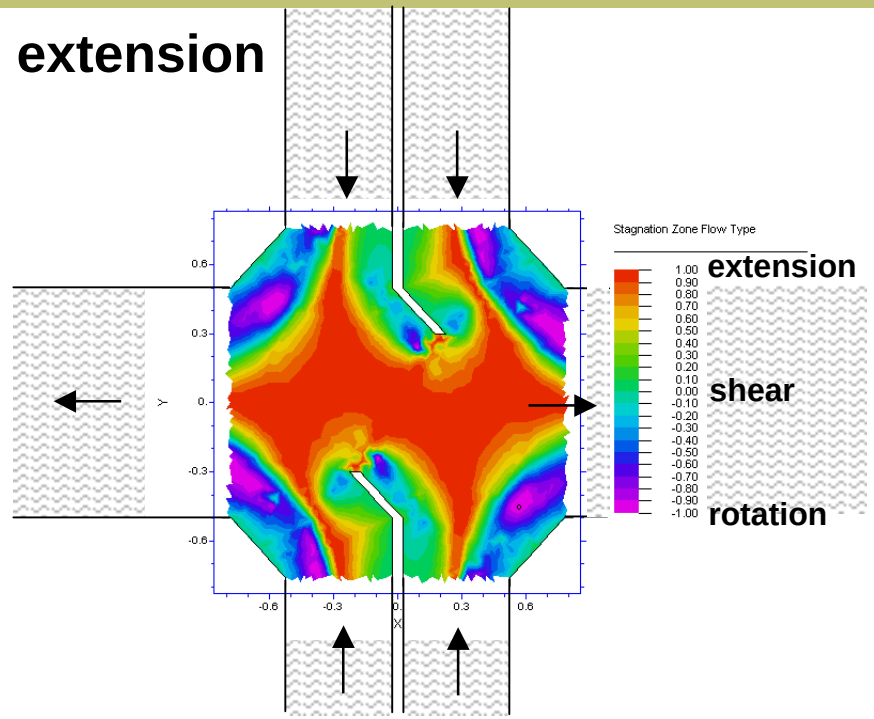
Micro-channel analog

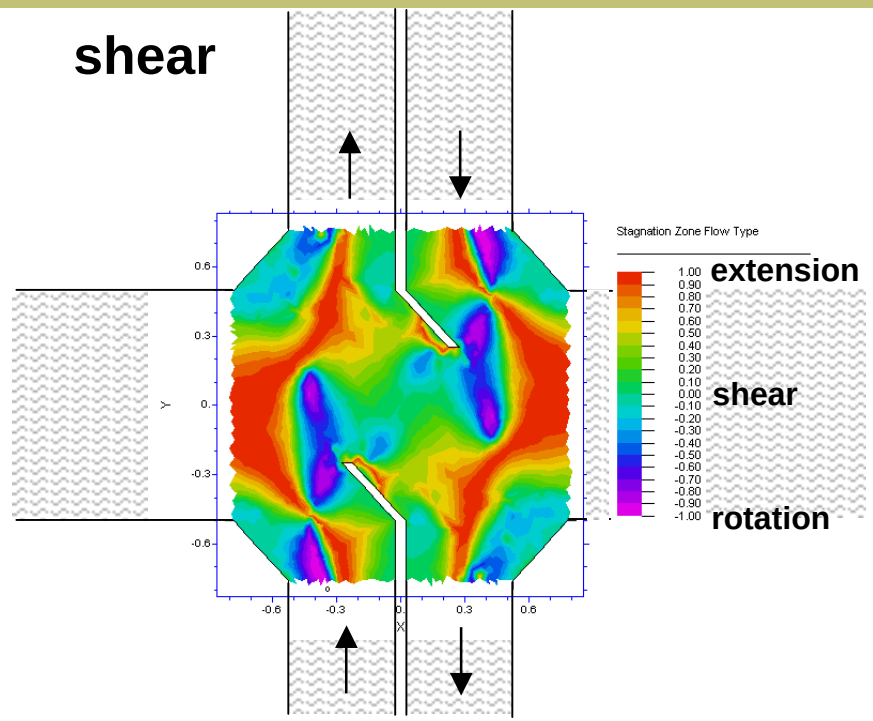


Additional features:

- *Easily scalable and manufacturable.*
- ***3D** control of flow and drop positions is possible.*
- *Convenient for microscopy and other high-resolution probes.*
- *A wider range of flow type, including pure shear, is possible.*

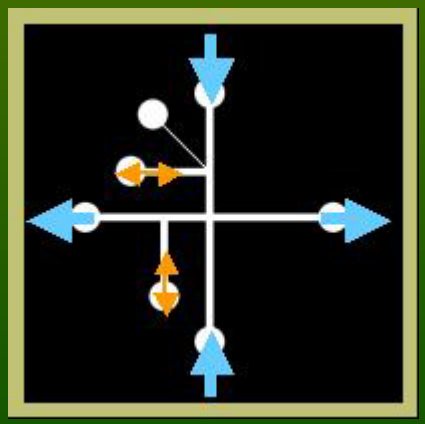
Flow Modeling
for device design





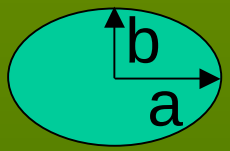
- 2D Stokes calculations.
- Rotational, shear, extensional and mixed flows selected by boundary conditions.
- In each case, the flow strength at the stagnation point is
  ~ 0.2 * narrow channel wall shear rate.

Apparatus



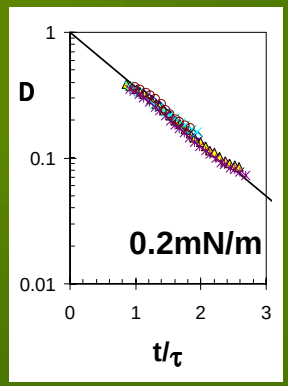
Preliminary results, Cross-channel

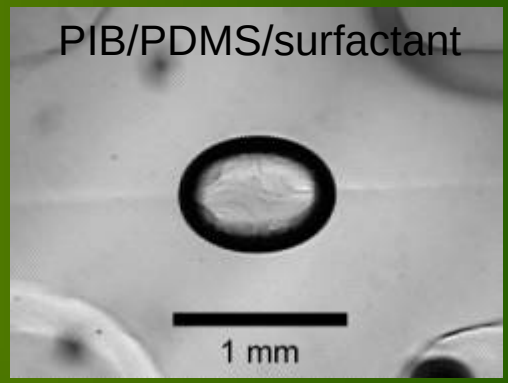
Drop deformation

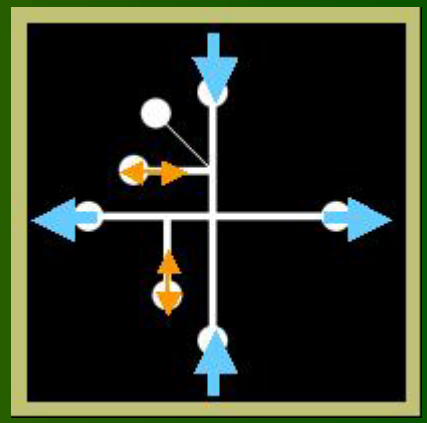


$$D = \frac{a-b}{a+b}$$

$$\tau_d = \eta_{eff} R/\sigma$$

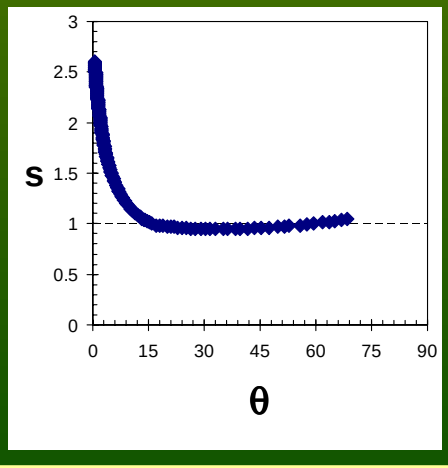


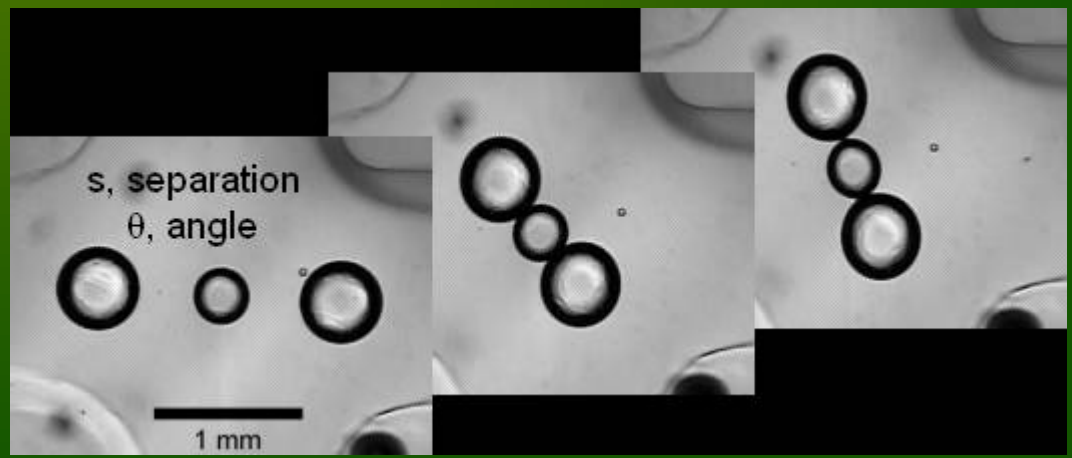




Control ports

Drop position



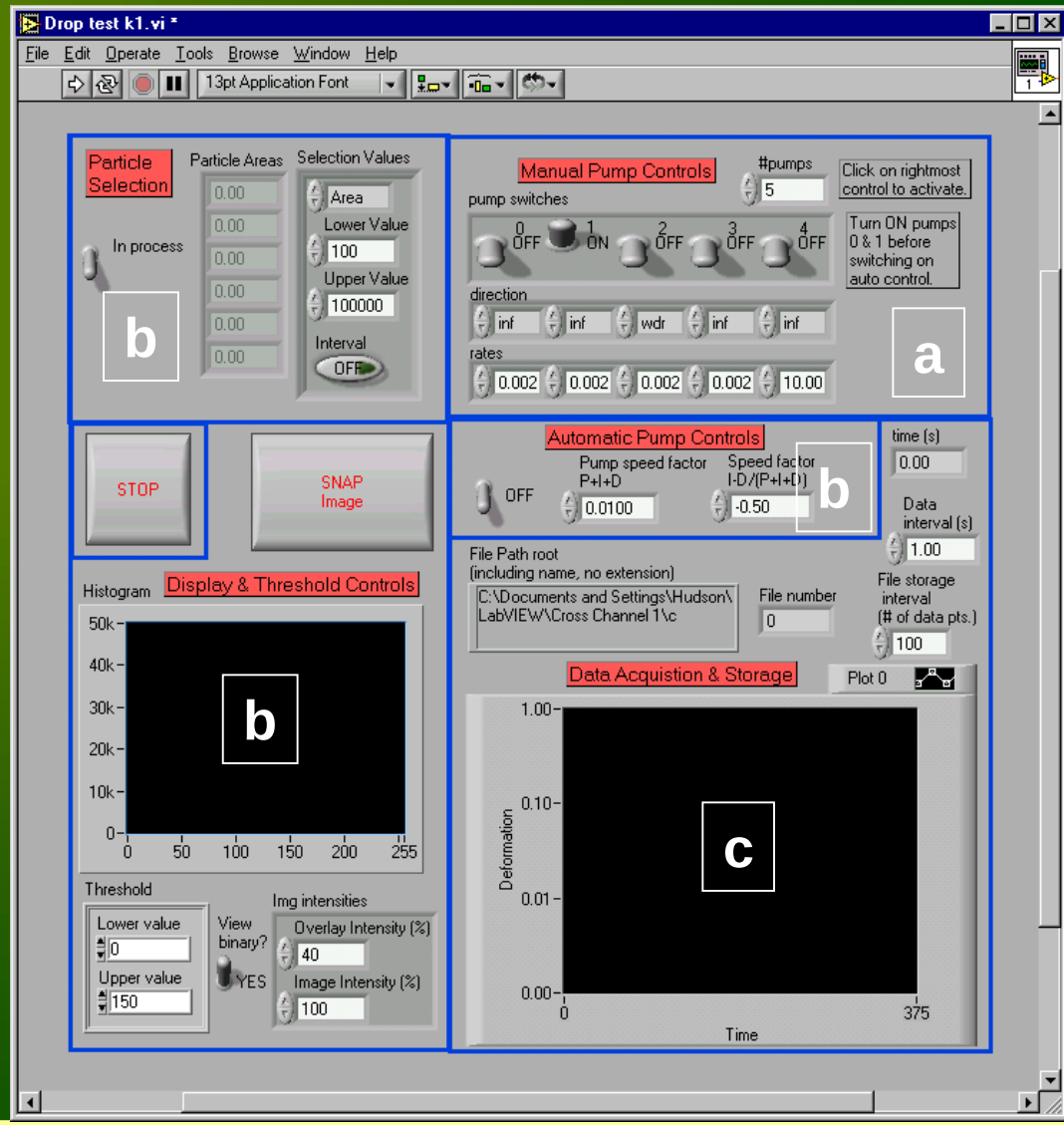


Computer control

a. Adjust pump speeds to regulate flow strength.

b. Image analysis feedback and PID control keeps drop(s) at the stagnation point.

c. Record drop deformation and position.

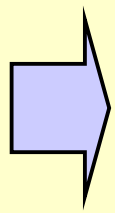


Drop deformation: measure **Relaxation** or **Steady** deformation?

Drop shape relaxation time

$$\tau_d = \eta_{eff} R/\sigma$$

1 Pa s
100 μm
10 mN/m



0.022 s

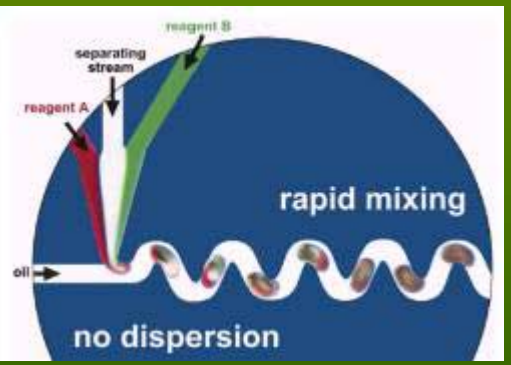
Need fast devices,
by minimizing flow resistance and capacitance,

or
Measure quasi-steady properties

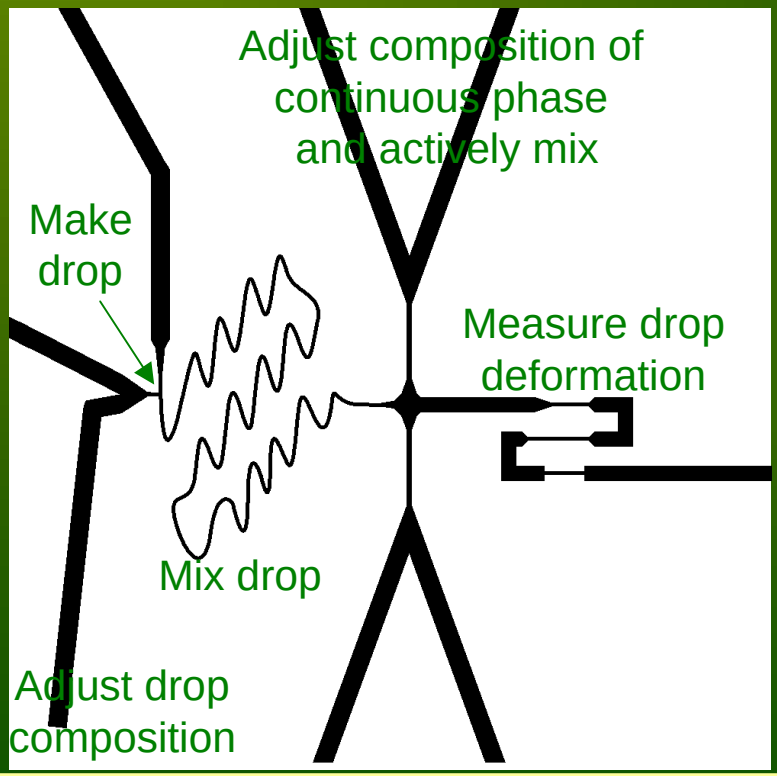
Specialized device for measuring interfacial tension

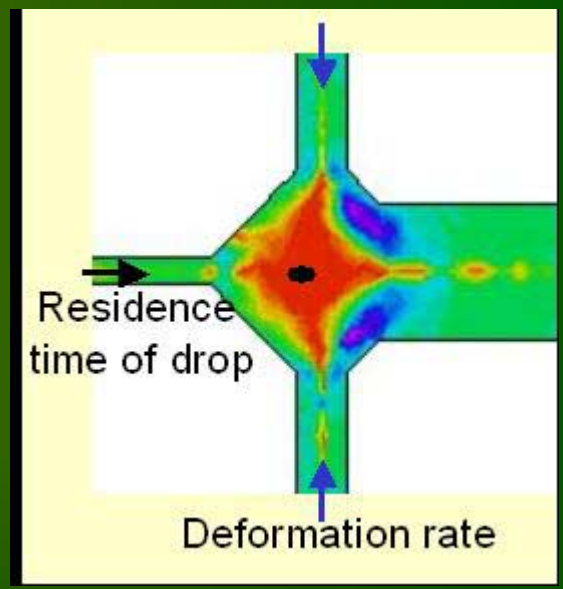
Measure quasi-steady drop deformation, appropriate for rapid time scales.

- Active and passive mixing of drop and continuous phase.
- Control residence time and deformation rate.



Song, Tice & Ismagilov
Angew. Chem. (2003)





Conclusions

- Microfluidic devices have been specially designed for rapid interfacial tension measurements.
- Peripheral results demonstrate the feasibility of:
  - flow modeling for device design / characterization
  - device fabrication
  - computer control and feedback methods.

Deliverables

- Design strategy, fabrication procedures and development tools (including flow modeling and control routines) will be available to members.